

Warm Forming Studies on Magnesium Alloys Under Uniaxial and Biaxial Deformation

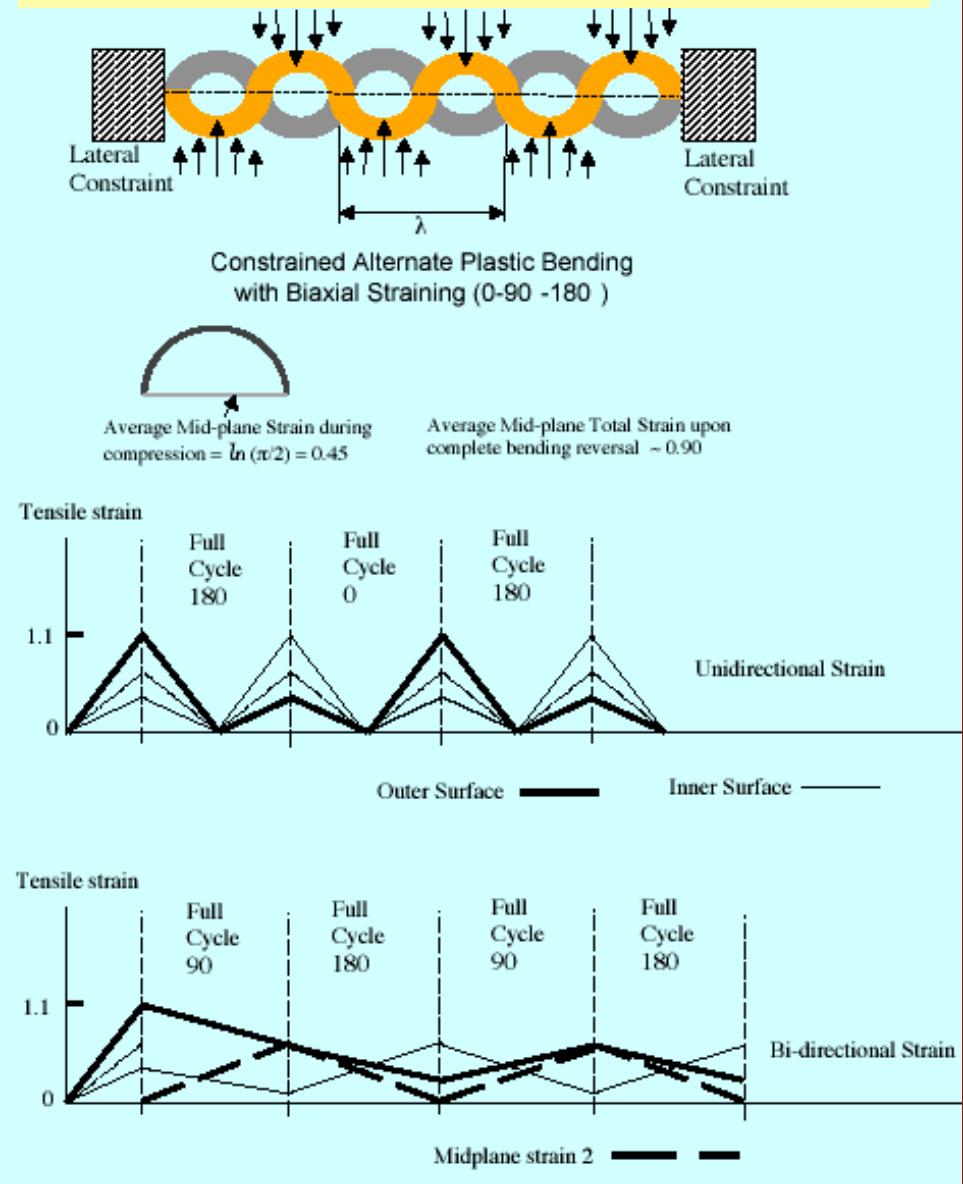
DMR 0314218 GOALI; P.I. Amit Ghosh and William Hosford, University of Michigan, Thixomat Inc. and DaimlerChrysler

Rationale and Approach:

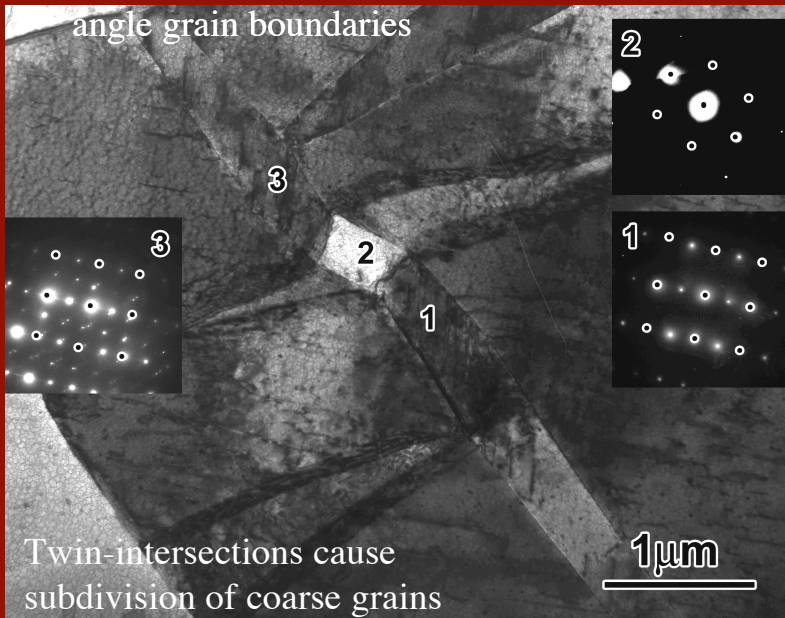
Warm forming of Mg alloys can overcome strain localization problem during part fabrication. However, homogeneous and stable, high angle grain boundary microstructure are required for reduced warm forming temperatures and for ease of manufacturing. The project has three elements: Deformation-based grain refinement approach, Alloy Chemistry modification and preparation by conventional ingot and by Thixo-molding, Warm Forming Experiments and Computer Modeling

Alloys: (i) Conventional AZ-31 alloy of current interest in industry, (ii) Zr-particle containing AZ-alloy for grain boundary pinning: use of Thixo-molding rapid solidification approach in a **sinewave form for billet processing**

BILLET PROCESSING SCHEME BY SEVERE DEFORMATION



Twin intersections create high angle grain boundaries



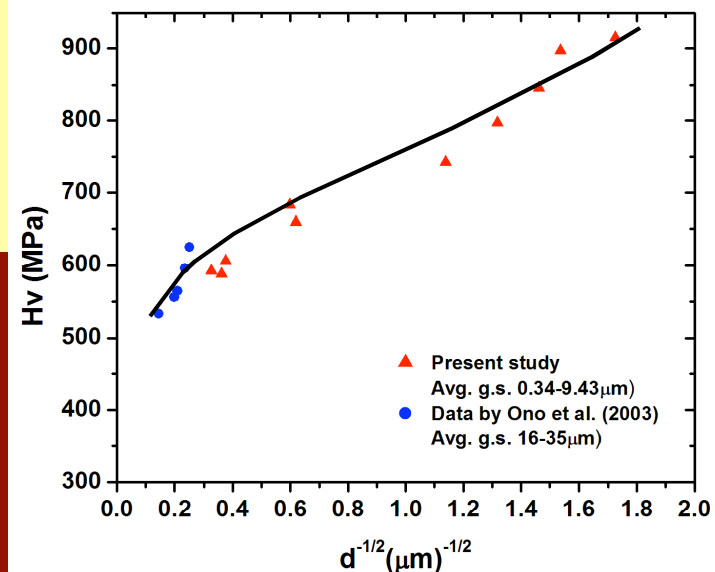
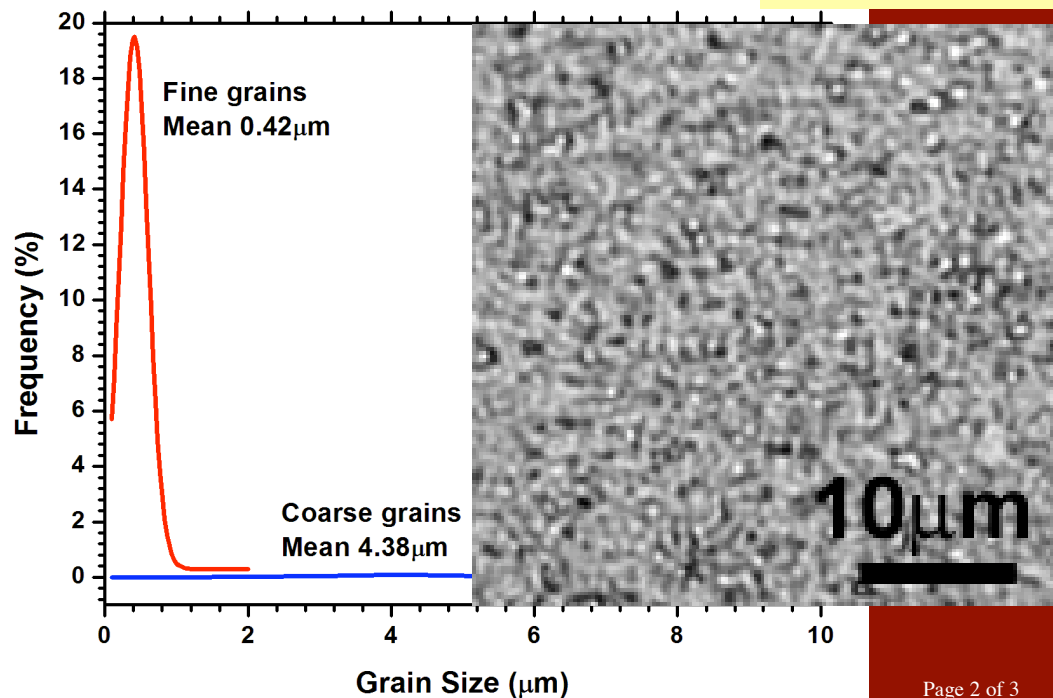
Twin-intersections cause subdivision of coarse grains

Billet after Second Stage

Alternate Biaxial Reversing Corrugation



Alternate Biaxial Reversing Corrugation (ABRC) process permits large billet sizes with homogeneous submicron grain structure and high angle grain boundaries to be fabricated. Unusual strengthening of a lean Mg alloy is noted. Preliminary warm tensile tests show promising formability enhancement at modest warm temperatures. 2004 Patent Application submitted (University of Michigan)



%Tensile Elongation at Warm Temperatures

Temperature, °C	Initial Billet	ABRC Process
150	50%	115%
200	56%	172%

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Broad Impact:

As a part of GOALI activity, Collaborative research is underway with Dr. Ray Decker and his team at Thixomat, Inc. in creating billets of rapidly solidified AZ-Mg alloy containing Zr in a sinewave mold. By the end of 2004, initial billets are expected to be ready. Collaborative effort with DaimlerChrysler team under Dr. Suresh Rama is continuing in evaluation of warm formability of existing Mg alloys. Other Industry participation has been with General Motors, USAMP and Air Force Research Laboratory.

Publications:

R. M. Cleveland et al., *Mat. Sci.Eng.* A351 (2003), p. 228-236.

D. H. Bae et al., *Met. and Mat. Trans.*, 34A, (2003), p. 2449-2463

P. D. Nicolaou et al., *Met and Mat. Trans.*, 35A, (2004), p. 2187

Yi Liu and Amit Ghosh, Microstructural Evolution during Severe Deformation of AZ-31 Mg Alloy under Non-Isothermal Process Condition, *Magnesium Technology*, (Jan. 2005), TMS

Q. Yang and A.K. Ghosh, Recrystallization and Mechanical Behavior of a Mg alloy Mg-3Al-1Zn at Elevated Temperature, to be submitted to *Mat. Sci. Eng. A*, 2004

Education:

Ruth Cleveland completed her PhD and is presently a staff researcher at Northrup-Grumman in California. Ms. Cleveland made major contributions to grain refinement and superplasticity studies.

Qi Yang, a PhD candidate at the University of Michigan has been a major contributor to studies of grain refinement in Mg alloys using Constrained Sinewave dies. Mr. Yang's experimental research and his deformation modeling work based on Recovery-Dislocation Storage model will lead to a PhD thesis within the next 16-20 months.

Dr. Yi Liu, a post doctoral fellow at the University of Michigan has completed a study of the relationship mechanical response of Mg alloys as a function of ultrafine grain structure, due to be published by Magnesium Technology 2005. Dr. Liu has enhanced his education in the area of Deformation Processing mechanics by combining with his expertise in Electron Microscopy.

Mr. David Alberts, an undergraduate student in Materials Engineering, is scheduled to begin his research studies on our project in the Fall of 2004.